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Developments in LIMB (Limestone Injection Multistage Burner) Technology

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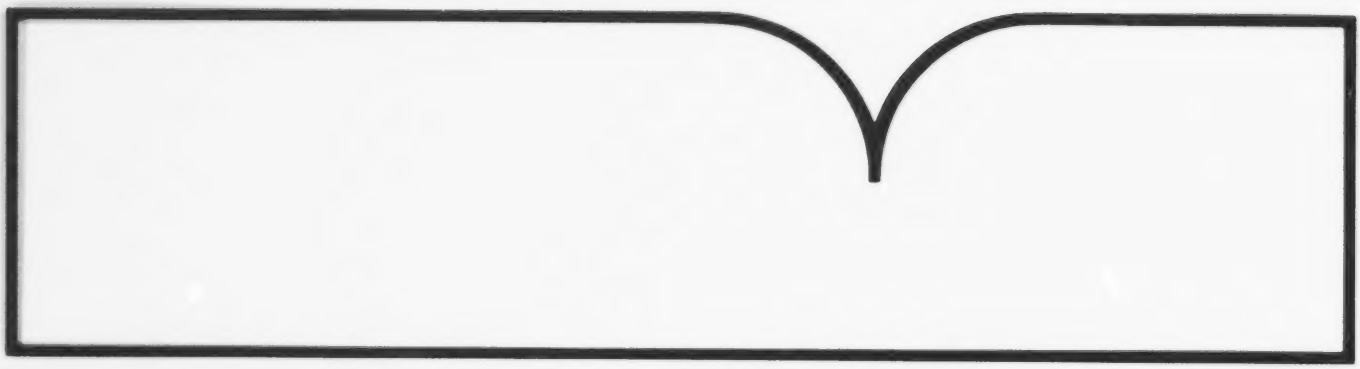

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DEVELOPMENTS IN LIMB TECHNOLOGY

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15. SUPPLEMENTARY NOTES Author Drehmel's mail drop is 4; his phone number is 919/541-7505.

16. ABSTRACT The paper describes the most recent results from the Limestone Injection Multistage Burner (LIMB) program, results from the wall-fired demonstration. Tests were conducted to determine the efficacy of commercial calcium hydroxide--$Ca(OH)_2$--supplied by Marblehead Lime Co. and of calcium-lignosulfonate-modified $Ca(OH)_2$. Performance of the modified sorbent was slightly better than that of the commercial sorbent. Both sorbents easily provided 50% capture of SO_2 at a calcium to sulfur molar ratio of 2.0 or less, which is the goal of the LIMB program. The paper also lists the major conclusions from the LIMB program to date.

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Pollution	Pollution Control	13B
Coal	Stationary Sources	21D
Burners	Limestone Injection Multistage Burners (LIMB)	13A
Limestone		08G
Combustion	Calcium Lignosulfonate	21B
Calcium Hydroxides		07B
Sulfur Dioxide		

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DEVELOPMENT IN LIMB TECHNOLOGY

INTRODUCTION

During the past several years, the EPA has sponsored control technology development work with the intent of providing abatement options for potential acid rain precursors. Some of these come with curious acronyms such as ADVACATE (ADVAnced siliCATE low temperature dry injection), E-SO_x (Electrostatic precipitator modifications to allow dry scrubbing for sulfur oxides, SO_x), and LIMB (Limestone Injection, Multistage Burners). The objective of all these processes is to capture at least 50 percent of the sulfur dioxide (SO_2) in a flue gas stream at a cost (in terms of \$/ton SO_2 removed) which is competitive with wet or dry flue gas desulfurization (FGD). In addition, LIMB is to lower emissions of nitrogen oxides (NO_x) to less than 0.5 lb/10^6 Btu by the use of multistage burners.

While ADVACATE and E-SO_x are still being studied at the pilot scale, LIMB has progressed to full-scale demonstration. Advancement to demonstration has come as the result of many years of EPA-sponsored research and development including tests at large pilot and prototype facilities. The LIMB program has consisted of five activity areas: fundamentals, pilot and prototype scale tests, modelling, cost analysis, and demonstration. Fundamentals have focused on the kinetics of potential LIMB reactions (e.g., calcination and sulfation) and on properties of limestone and limestone products to identify and optimize properties that produce high reactivity for SO_x capture. Pilot and prototype scale tests have provided information on the effect of the furnace conditions on LIMB, on the effect of LIMB on furnace operations, and on the operation of the extant particulate collection device which is almost always an electrostatic precipitator (ESP). Modelling is used to analyze and extrapolate test data and to provide input to the fourth area (cost analysis) which compares LIMB to alternatives. Finally, demonstration provides the data necessary for generalization of the technology to the private sector.

The LIMB program calls for demonstration at two sites. One of these sites is a wall-fired power plant, and the other is a tangentially fired (T-fired) power plant. The wall-fired plant is the subject of this paper and is described below. The T-fired plant is a nominal 180 MWe constructed by Combustion Engineering and is located in Yorktown, Virginia. Because of the difference in firing systems, the flow patterns in wall- and T-fired boilers are significantly different. The flow pattern affects the mixing and the temperature history of injected sorbent particles. Thus, it is essential to test LIMB with these two types of firing systems which are the only two major types of firing systems for large scale utility boilers.

It is the purpose of this paper to describe the most recent results from the wall-fired LIMB demonstration program. The project is being conducted with the Babcock & Wilcox (B&W) 105 MWe Unit 4 boiler at Ohio Edison's Edgewater Station in Lorain, Ohio. The results are preliminary and subject to further optimization. Consequently, it is important to bear in mind important conclusions from the other parts of the LIMB Program which will aid in interpretation of the demonstration results. These conclusions are provided below in the background section.

BACKGROUND

Each of the LIMB activity areas has contributed important conclusions which explain decisions in the formulation of the LIMB demonstration and which may be useful in understanding the results recently obtained. Conclusions from the fundamentals area are as follows:

1) Both calcium carbonate ($CaCO_3$) and calcium hydroxide [$Ca(OH)_2$] convert rapidly to calcium oxide (CaO) at furnace conditions; SO_2 capture is determined by reactivity of the CaO produced.

2) The reactivity of CaO is determined by its surface area, particle size, and pore size distribution; CaO produced from $Ca(OH)_2$ has the more favorable surface area and pore size distribution for SO_2 capture.

3) Loss of surface area of CaO, called sintering, renders high surface precalcined CaO less effective than high surface area CaO formed from $Ca(OH)_2$ in the furnace.

4) The reactivity of CaO may be enhanced by the addition of certain metal ions or surfactants; the mechanism for the metals is uncertain, but recent information shows that surfactants incorporated into the water of hydration for $Ca(OH)_2$ decrease the sintering rate of the CaO formed in the furnace after injection.

The first conclusion from pilot and prototype testing is in agreement with the results from fundamentals. The first and rest of these conclusions are as follows:

1) $Ca(OH)_2$ is a superior SO_2 sorbent to either $CaCO_3$ (limestone) or CaO; the performance of $Ca(OH)_2$ can be enhanced by the addition of calcium lignosulfonate (a surfactant).

2) For $Ca(OH)_2$ the optimum injection temperature into a typical furnace is 2300°F (1250°C); incorporation of calcium lignosulfonate allows injection at slightly higher temperatures without adverse effects.

3) Deposits formed in high temperature zones of the furnace as a result of sorbent injection are friable and appear to be readily removable with increased sootblowing.

4) Injection of $Ca(OH)_2$ increases the resistivity of the fly ash and decreases the efficiency of an ESP; the resistivity and efficiency can be restored by humidification which will also reactivate unused CaO for further SO_2 capture at low temperatures.

5) The reactivity of commercial $Ca(OH)_2$ varies enough to affect attainment of SO_2 capture objectives; the sorbent supplied by Marblehead Lime Company was selected based on a combination of good reactivity and low cost.

Conclusions from the modeling and cost areas are as follows:

1) Heat transfer and mixing models are effective in predicting the location of optimum injection; the mixing model shows that poor injection is avoided only with great care and that poor mixing can cut overall SO_2 capture in half.

2) The sulfation model shows that the good capture resulting from high surface area sorbents is available only at small particle sizes; large particle sizes increase pore diffusion and mask differences in basic reactivity.

3) Because $Ca(OH)_2$ naturally has a much smaller particle size than $CaCO_3$, the cost to grind $CaCO_3$ to the same size would make it more expensive than $Ca(OH)_2$.

4) Because LIMB is more operating cost intensive, but less capital cost intensive, than wet or even dry FGD, LIMB competes well in older boilers or those with lower load factors.

EXPERIMENTAL

The boiler being used for the wall-fired LIMB demonstration is of the radiant, Carolina design and burns eastern bituminous coal. It has been in operation since June 1, 1957. The boiler has 12 burners fired from a single wall in a 3 column by 4 row array. The original burners were B&W circular burners, recently changed to B&W XCL low-NO_x burners for the "MB" (multistage burner) part of the LIMB program. Particulates are collected by a 6-field Lodge Cottrell ESP which is only 4 years old. With respect to the "LI" (limestone injection) part of LIMB, the system for injection can deliver sorbent to any two of three levels in the boiler. These levels are elevations 181, 187, and 191 which have eight nozzles

each in the front wall. In addition, there are two nozzles on each side wall at elevation 187, about 3.5 and 6.5 feet (107 and 198 cm, respectively) from the front wall. The elevations are at and slightly above the "nose" of the boiler. It is in this area that the average injection temperature of 2300°F (1250°C) is available. Obviously, the temperature varies across a horizontal cross section of the boiler because of heat transfer to the water-cooled walls. In order to provide sorbent at these elevations, there are two air conveying systems consisting of differential weight loss feeders which drop sorbent to a star valve and down to the transport air jet. The feeders are supplied by a small hopper or "day silo" inside the boiler house, and that hopper is in turn supplied by an external silo filled directly by truck.

Accurate determination of LIME effectiveness is dependent on measurements of sorbent feed rate, outlet SO_2 concentration, and inlet SO_2 concentration as determined by coal feed rate and coal sulfur content. The "day silo" is also equipped with local cells for an independent check on sorbent feed rate. The outlet SO_2 concentration is measured by a continuous emission monitor that analyzes the flue gas between the stack and the induced draft fan after the ESP. Flue gas is extracted for the monitoring system through a filter in the stack and another filter in a heated box before being drawn to an ultraviolet analyzer. Both filters are hot (approximately 300°F -- 150°C) to avoid reactions of unused sorbent on the filter, and contamination is slight because the upstream ESP is highly efficient. The coal feed rate is determined by computation from the boiler heat rate, using equations from the design of the Edgewater boiler which B&W considers proprietary. The coal sulfur content is determined by sampling of the coal just before injection into the furnace. As noted above, coal feed rate and coal sulfur concentration are used to compute the inlet SO_2 concentration which is verified by the outlet monitor during periods before and well after any periods of sorbent injection.

RESULTS

Test periods at Edgewater were as follows:

1) Low NO_x burner characterization without limestone injection during early July 1987.

2) Shakedown of the system (primarily the feed system) from late July to late August 1987.

3) SO_2 removal tests with commercial $Ca(OH)_2$ during September 1987 with injection primarily at elevation 181.

4) SO_2 removal tests with calcium lignosulfonate-modified $Ca(OH)_2$ during the last week of September 1987 before a

regularly scheduled outage. The modified sorbent was prepared from the same CaO used to make the normal commercial $Ca(OH)_2$. Injection was at elevation 181. Unlike previous tests in which all injections were with no tilt to the nozzle, the last test with the modified sorbent was with the nozzles tilted 15 degrees down.

All the elevation 181 capture data taken are shown in Figure 1 as a function of the calcium to sulfur molar ratio. By dividing the SO_2 capture by the calcium to sulfur ratio, the utilization of CaO is obtained and is plotted in Figure 2. Note that utilization decreases slightly with increasing calcium to sulfur ratio. Figure 3 shows the data for the commercial sorbent only, and Figure 4 the data for sorbent modified with calcium lignosulfonate. These latter two figures present both the SO_2 capture and the CaO utilization as a function of the calcium to sulfur ratio.

DISCUSSION OF RESULTS

Statistical analysis of the data provides a useful interpretation of the results of the Edgewater demonstration to date. Figures 5 and 6 show the predicted SO_2 captures for unmodified and modified sorbents, respectively. The middle line is the average prediction, and the outside lines show the prediction for upper and lower bounds as defined by two standard deviations from the average. These figures show that LIMB easily meets its objective of 50 percent sulfur capture at a calcium to sulfur ratio of 2.0 or less. The average lines for both sorbents are shown together in Figure 7. The sorbent treated with calcium lignosulfonate is more effective than the untreated sorbent although the difference is small. Comparison of the lower bound of the treated sorbent with the upper bound of the untreated sorbent shows that there is a positive difference at calcium to sulfur ratios above 1.5. Unfortunately there was insufficient time for testing before the scheduled outage to begin optimization for either sorbent. As a result, it is too early to draw any conclusions about the ultimate difference between the two.

After the scheduled outage, a full scale humidifier will be brought on line. As noted previously, the humidifier lowers the resistivity of the fly ash to the benefit of the ESP and reactivates unused lime for further SO_2 capture at low temperatures. Based on pilot plant experience, it is expected that an extra 10-15 percent of SO_2 will be captured at low temperature. This would raise total capture to 65-70 percent at a calcium to sulfur ratio of 2.0.

Once the humidifier is in continuous operation, the system will be tested in a parametric array which will identify optimum conditions for capture with and without treatment of the $Ca(OH)_2$ with calcium lignosulfonate. During this period, a more definitive

comparison between treated and untreated sorbents will be determined. Also decided will be the optimum injection elevation, angle, and velocity. Once these have been established, the injection system can begin long-term testing to determine the effect of injection on boiler operation. Meanwhile, conditions for humidification will be varied to optimize the low temperature SO_2 capture. Eventually, all systems will be configured at their optimum operation for SO_2 capture to establish reliability of the LIMB-with-humidification process.

FIGURE 1
SULFUR CAPTURE AT THE EDGEWATER DEMONSTRATION

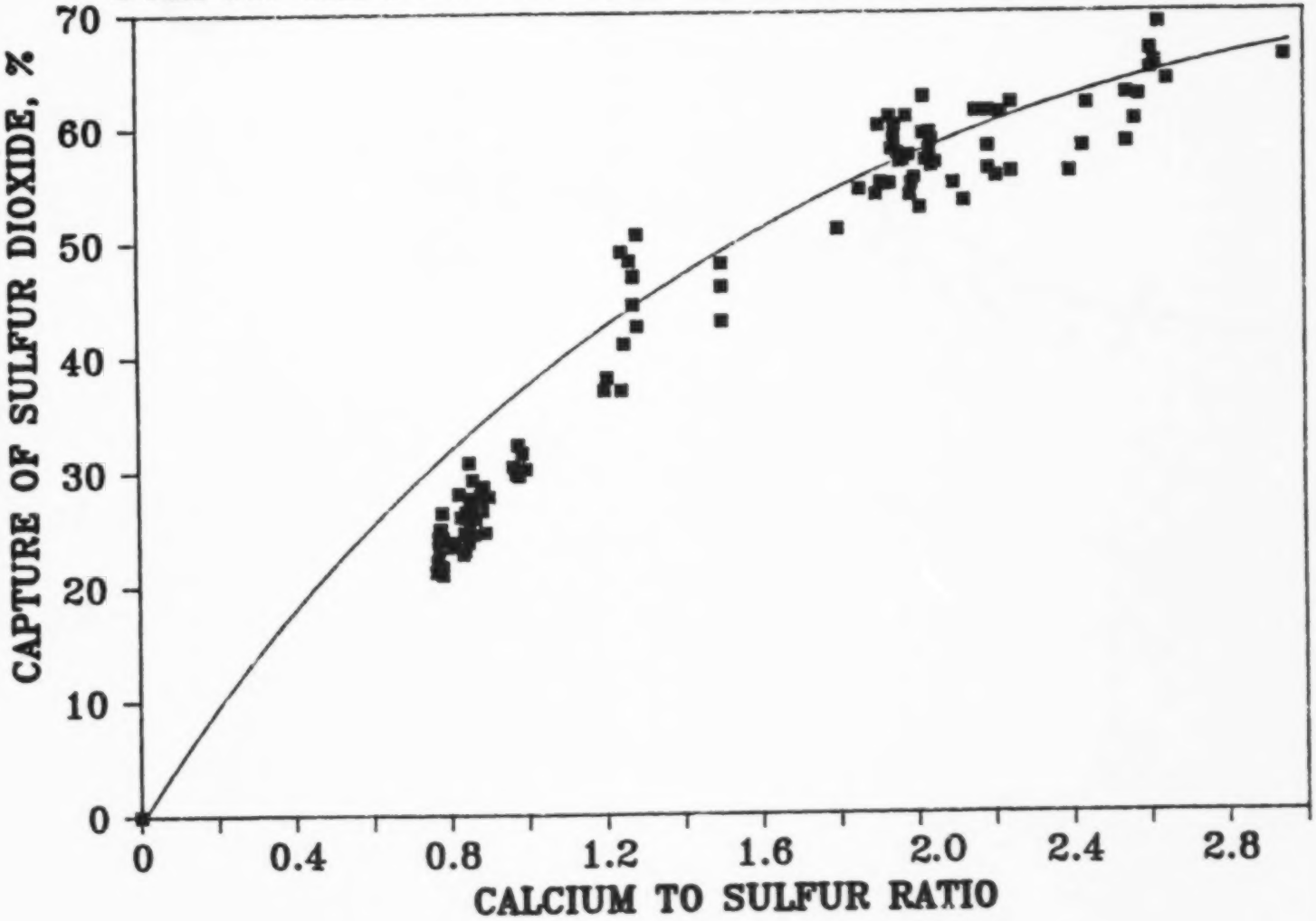

FIGURE 2

CALCIUM UTILIZATION AT THE EDGEWATER DEMONSTRATION

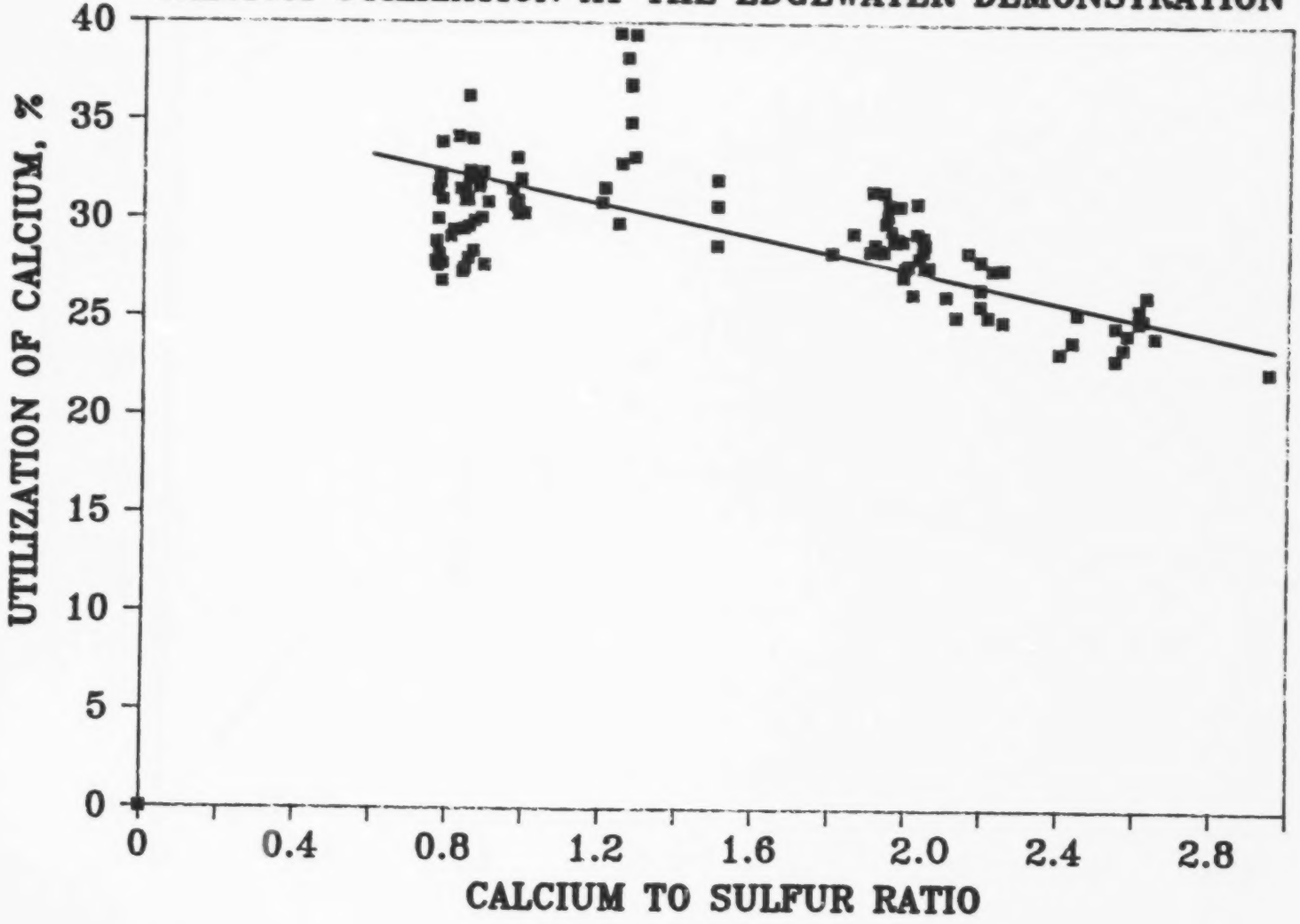

FIGURE 3
RESULTS FOR COMMERCIAL CALCITIC HYDRATE

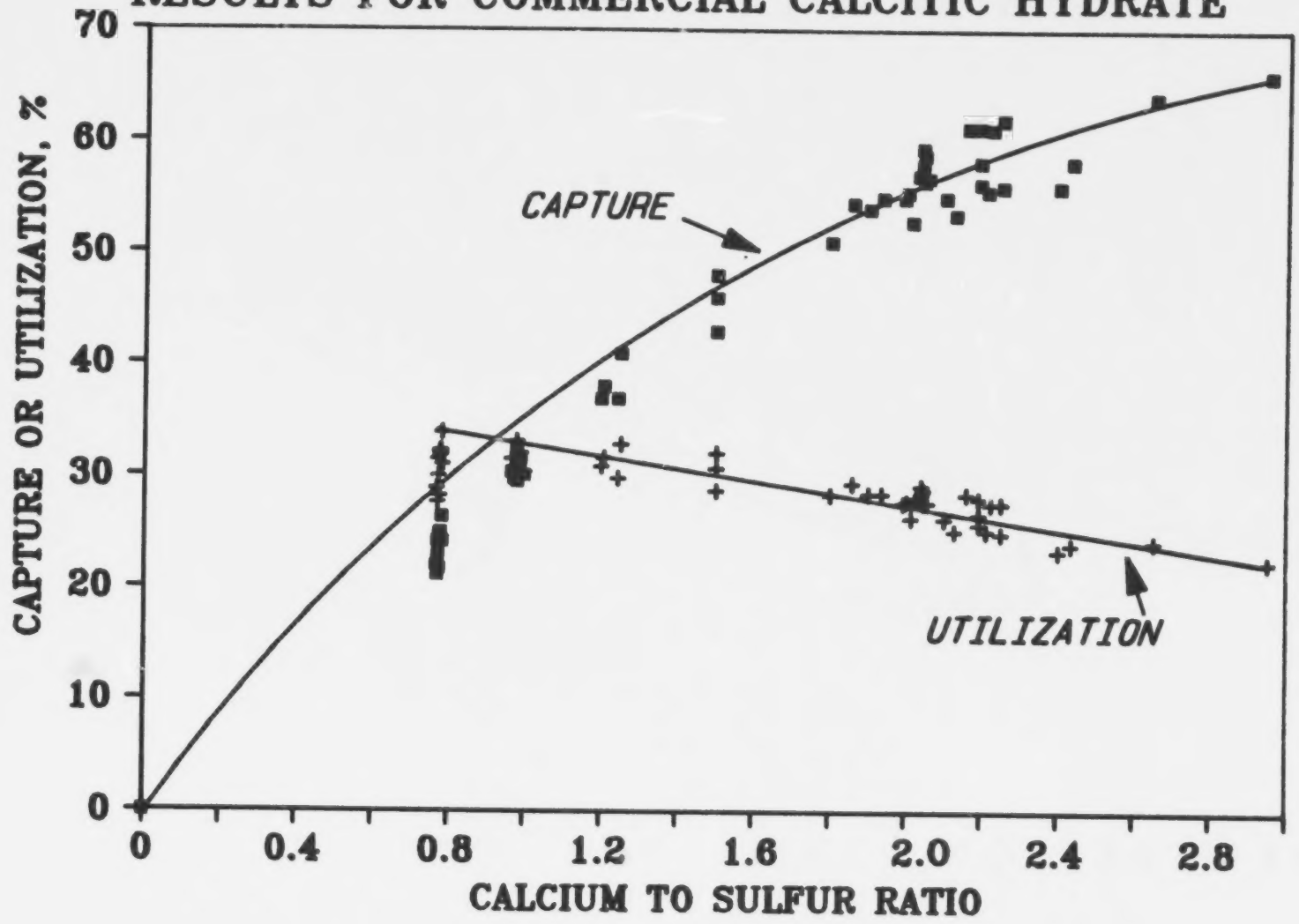

FIGURE 4
RESULTS FOR MODIFIED CALCITIC HYDRATE

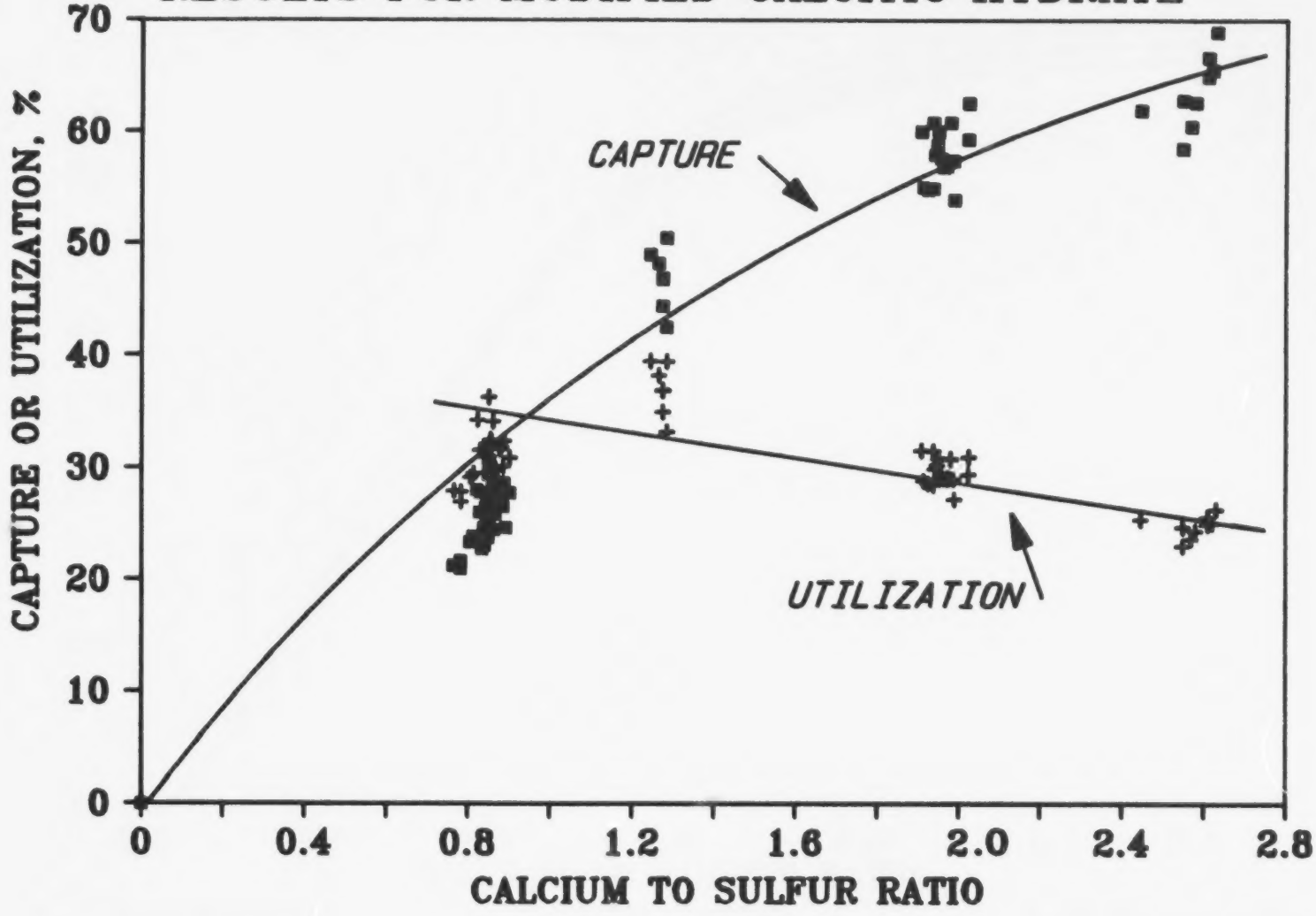

FIGURE 5
STATISTICAL FIT FOR UNMODIFIED SORBENT

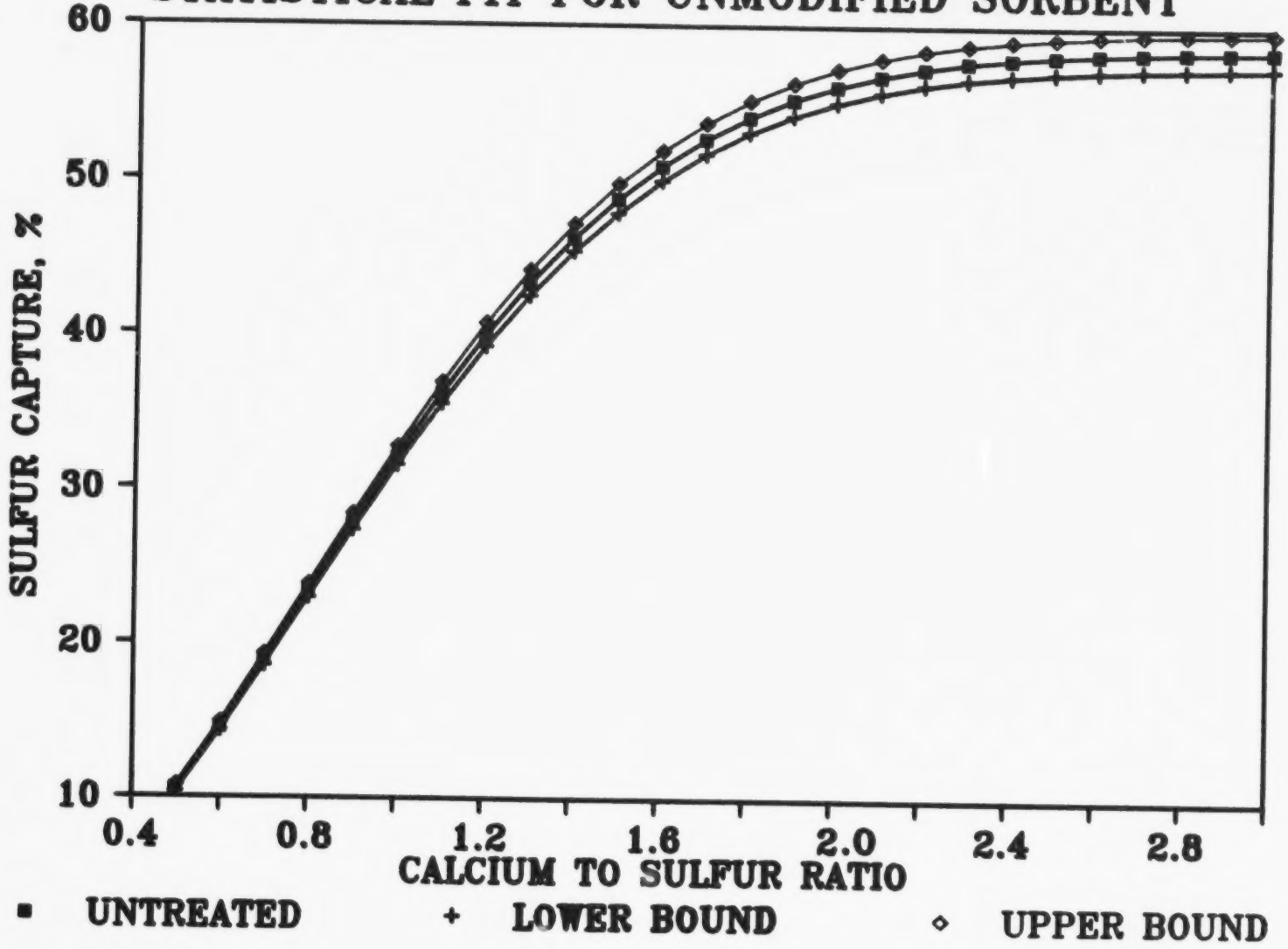

FIGURE 6
STATISTICAL FIT FOR MODIFIED SORBENT

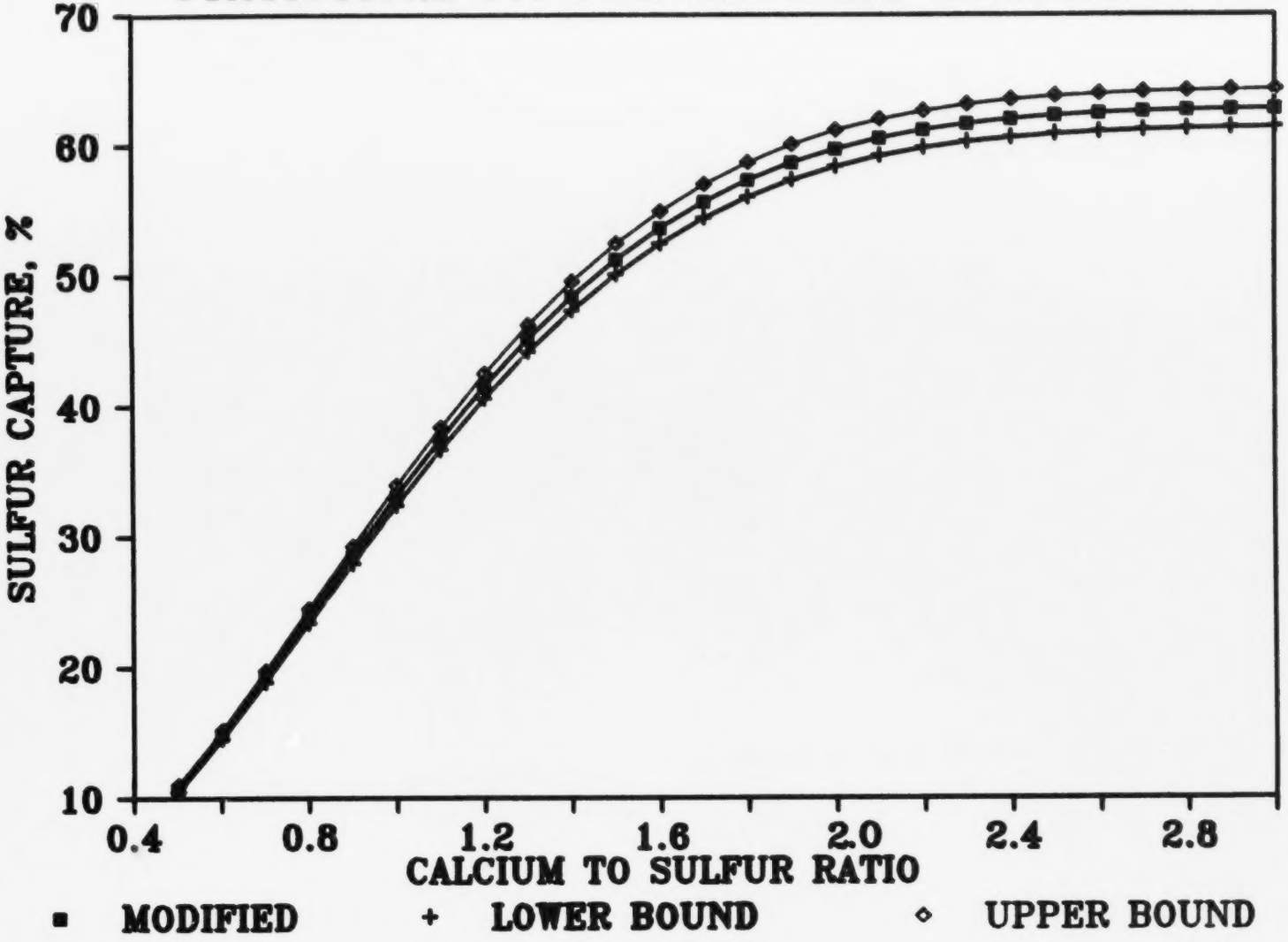

FIGURE 7
STATISTICAL FIT: MODIFIED VERSUS UNMODIFIED